UNITED STATES MARINE CORPS
COMBAT ENGINEER INSTRUCTION COMPANY
MARINE CORPS ENGINEER SCHOOL
PSC BOX 20069
CAMP LEJEUNE, NORTH CAROLINA 28542-0069

C-14B01
8 May 01
(00 POI)

STUDENT HANDOUT

SURVIVABILITY

1. PURPOSE: The purpose of this period of instruction is to provide you with the knowledge of bunker and revetment construction and the tools required to accomplish this mission.

2. INTRODUCE LEARNING OBJECTIVES

a. TERMINAL LEARNING OBJECTIVE (S):

(1) Provided a mission, construction site, specifications, engineer carpentry tools, timber cut to specification, attaching hardware, and references, place timber to meet mission specifications, utilizing proper tools while observing safety precautions per the references. (1371.01.15)

(2) Provided a mission, a defensive position, personnel, tools, equipment, materials, and references, place revetment materials to provide protection from enemy fire per the references. (1371.04.01)

b. ENABLING LEARNING OBJECTIVE (S):

(1) Without the aid of references, provided specifications, an SL-3 complete 250 cfm compressor, materials to operate on and safety devices, operate the components of the 250 cfm compressor to meet the specifications per the references. (1371.01.15a)

(2) Without the aid of references, provided specifications, an SL-3 complete 250 cfm compressor, materials and safety devices, as a member of a team, place timber components of a bunker to meet the specifications per the references. (1371.01.15.b)

(3) Without the aid of references, provided specifications, an SL-3 complete 250 cfm compressor, bunker without a roof, materials and safety devices, as a member of a team, place roof components for a bunker to meet the specifications per the references. (1371.01.15c)

(4) Without the aid of references, provided a mission, a defensive position, tools, equipment and materials, as a member of a team, place a sandbag revetment per the references. (1371.04.01a)

(5) Without the aid of references, provided a mission, a defensive position, tools, equipment and materials, as a member of a team, revet a trench per the references. (1371.04.01b)

BODY

1. Survivability Positions

a. General: There are two major categories for Survivability Positions. The two categories are Fighting Positions and Protective Positions. An example of fighting positions allow us to engage the enemy with direct or indirect fire, Examples of these positions include individual positions, perimeter bunkers, crew served weapons pits, and trenches. Protective positions do not allow personnel to engage the enemy. A few examples of Protective positions are underground bunkers, and vehicle hides.

b. Construction Materials: Materials used in Survivability Positions act as either Shielding or structural components.

(1) Shielding: This Material is used on the roofs and sides of positions to provide personnel or equipment protection from direct or indirect fire. Listed below are Materials used for shielding.

(a) Soil
(b) Steel
(c) Concrete
(d) Rock
(e) Brick and Masonry
(f) Wood
(g) Snow and Ice

(h) The thickness used will vary according to the size and type of weapons you expect to be engaged with and the material you use for shielding. This is shown in the below listed Tables, which were taken from the FM 5-103.

Material Thickness, in inches, required to protect Against direct fire HE shaped-Charge

Material	73-mm RCLR	82-mm RCLR	85-mm RPG-7	107-mm RCLR	120-mm Sagger
Aluminum	36	24	30	36	36
Concrete	36	24	30	36	36
Granite	30	18	24	30	30
Rock	36	24	24	36	36
Snow, packed	156	156	156	-	-
Soil	100	66	78	96	96
Soil, frozen	50	33	39	48	48
Steel	24	14	18	24	24
Wood, dry	100	72	90	108	108
Wood, green	60	36	48	60	66

Note: Thickness assumes perpendicular impact

Material Thickness, in inches, required to protect against direct hits by direct fire projectiles

Material	Small caliber and machine gun (7.62-mm) fire* at 100 yd	Antitank Rifle (76-mm) fire* at 100 yd	20-mm Antitank fire at 200 yd	37-mm Antitank fire at 400 yd	50-mm antitank fire at 400 yd	75-mm Direct fire at 500 to 1,000 yd	Remarks
SOLID WALLS**							
Brick masonry	18	24	30	60	-	-	None
Concrete, not rein.***	12	18	24	42	48	54	Plain formed-concrete walls
Concrete, reinforced	6	12	18	36	42	48	Structurally reinforced with steel
Stone masonry	12	18	30	42	54	60	Values are guides only
Timber	36	60	-	-	-	-	Values are guides only
Wood	24	36	48	-	-	-	Values are guides only
Walls of loose material between boards**							
Brick rubble	12	24	30	60	72	-	None
Clay, dry	36	48	-	-	-	-	Add 100% to thickness if wet
Gravel/small crushed rock	12	24	30	60	72	-	None
Loam, dry	24	36	48	-	-	-	Add 50% to thickness if wet
Sand, dry	12	24	30	60	72	-	Add 100% to thickness if wet
Sandbags filled with							
Brick rubble	20	30	30	60	70	-	None
Clay, dry	40	60	-	-	-	-	Add 100% to thickness if wet
Gravel/small crushed rock	20	30	30	60	70	-	None
Loam, dry	30	50	60	-	-	-	Add 50% to thickness if wet
Sand, dry	20	30	30	60	70	-	Add 100% to thickness if wet
Parapets of							
Clay	42	60	-	-	-	-	Add 100% to thickness if wet
Loam	36	48	60	-	-	-	Add 50% to thickness if wet
Sand	24	36	48	-	-	-	Add 100% to thickness if wet
Snow and Ice							
Frozen snow	80	80	-	-	-	-	None
Frozen soil	24	24	-	-	-	-	None
Icecrete (ice+aggregate)	18	18	-	-	-	-	None
Tamped snow	72	72	-	-	-	-	None
Unpacked snow	180	180	-	-	-	-	None

* One burst of five shots.

** Thickness to nearest ½ ft.

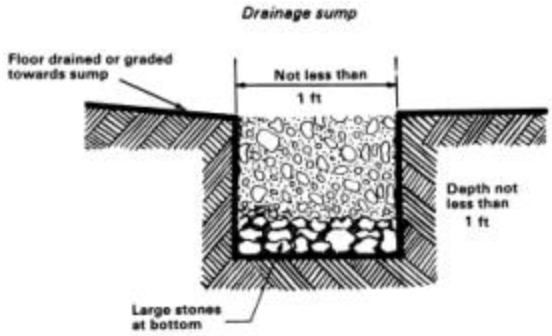
*** 3,000 psi concrete.

Note: Except where indicated, protective thickness numbers are for a single shot only. Where weapons place five or six direct fire projectiles in the same area, the required protective thickness is approximately twice that indicated. Where no values are given, material is not recommended.

Material Thickness, in inches, required to protect against
Indirect fire fragmentation and blast exploding 50 feet away

Material	Mortars 82-mm	120-mm	122-mm Rocket	HE Shells 122-mm	152-mm	Bombs 100-lb	250-lb	500-lb	1,000-lb
Solid Walls									
Brick masonry	4	6	6	6	8	8	10	13	17
Concrete	4	5	5	5	6	8	10	15	18
Concrete, Rein.	3	4	4	4	5	7	9	12	15
Timber	8	12	12	12	14	15	18	24	30
Walls of loose material between boards									
Brick rubble	9	12	12	12	12	18	24	28	30
Earth *	12	12	12	12	16	24	30	-	-
Gravel, small stones	9	12	12	12	12	18	24	28	30
Sandbags, filled with									
Brick rubble	10	18	18	18	20	20	20	30	40
Clay *	10	18	18	18	20	30	40	40	50
Gravel, small stones, soil	10	18	18	18	20	20	20	30	40
Sand *	8	16	16	16	18	30	30	40	40
Loose parapets									
Clay *	12	20	20	20	30	36	48	60	-
Sand *	10	18	18	18	24	24	36	36	48
Snow									
Tamped	60	60	60	60	60	-	-	-	-
Untamped	60	60	60	60	60	-	-	-	-
* Double values if material is saturated **NOTE:** Where no values are given, material is not recommended									

(2) Structural Components: These are used to hold the shielding material in place and provide protection to Personnel and Equipment. There are three Components used in building positions.



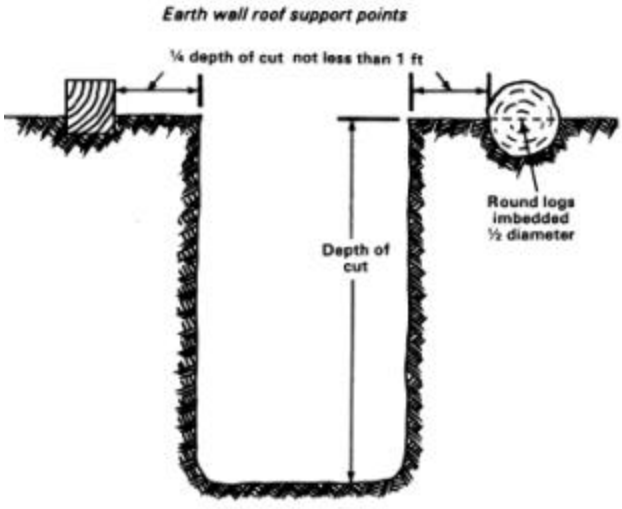
(a) Floors: These are most often the soil in the bottom of the position but can be made of wood, such as pallets placed on the soil. All position floors should have a drain sump dug into the floor as shown below.

(b) Walls: Walls can be either above ground or below ground (the sides of the cut).

1 Below ground walls:

a When building Fighting positions the sides of the hole that is dug will be the wall. The soil type the position is dug in may require revetment to prevent them from collapsing due to poor stability, and weather. Revetments will be covered in the in the construction sequence portion of this outline.

(1) When overhead cover is used, and supported by the soil wall, as shown below, the support material should be ¼ of the depth of the cut from the edge of the position. The support material is to be imbedded in the ground no less than ½ its diameter.



b If a protective position is being constructed, such as a bunker, it will have walls built similar to a standard wood frame structure. The components of the wall are:

(1) Sill. The sill is there to evenly distribute the load from the posts to the deck.

(2) Posts. Posts distribute load from cap to sill.

(3) Diagonal Bracing. Gives the bunker added support and prevents the structure from swaying and collapsing.

(4) Scab. Scabs provide needed additional support for caps, posts and sills.

(5) Cap. Caps transfer the load from stringers.

(6) Sheathing. Provides some protection when the bunker is not buried, but mainly is used to keep soil from filling up the bunker during back filling.

2 Above ground walls: Are constructed to defeat direct fire weapons or fragments from near miss impacts. The type of wall, the thickness of the wall, and the materials it will be constructed with will depend on the weapons it will need to defeat. If the wall is thick enough and stable they may have overhead cover.

(c) Roofs: Roofs can be easily designed to protect personnel and equipment from fragments and small caliber direct fire weapons. When being designed to protect from direct hits of large caliber weapons, such as artillery and mortars, the roof will require time and large amounts of material. Two types of roofs are used in position construction; Stringers and sheathing or laminated sheathing (no stringers). Both roof types will utilize several protective layers to minimize weapons effects and the effects of weather on the position. The protective layers will be covered in depth in the construction portion of this lesson.

1 Stringer and sheathing: Stringer size and spacing will depend on the weapons to be defeated. The Sheathing Material will be 1-inch material to defeat 82-mm contact bursts and 2-inch material should be used for weapons 120-mm and greater. Minimum stringer size will be 2x4 and the largest required will be 12x12. You can also use logs as stringers. The chart below shows what diameter log equals a dimensioned timber.

Dimensioned Timber size, in*	**Equivalent Round Timber (log) Diameter, in**
4 x 4	5
6 x 6	7
6 x 8	8
8 x 8	10
8 x 10	11
10 x 10	12
10 x 12	13
12 x 12	14
*** Sizes given are nominal and not rough cut Timber**	

2 Laminated Roof: The laminated roof is the strongest type of roof and is the most desired.

(a) Laminated roof is constructed in layers by alternating the direction of the sheathing material on top of the caps.

(c) The roof is completed once the minimum layers are attached. The minimum layers needed are as follows: 5 layers if you are using 2-inch material and 3 layers if you are using 3-inch material.

3. POSITION CONSTRUCTION: Individual positions are standard in design and simple to construct. The position we will be constructing is an underground bunker and a trench.

a. Excavation: This will be the most difficult and time consuming portion when constructing a position, however once excavation is completed most positions can be built utilizing Engineer pioneer hand tools and personnel.

(1) Mechanical assistance: We as Engineers have available to use some equipment that can aid us in excavation and construction of these positions the equipment we have available is listed below.

(a) Small Emplacement Excavator (SEE Tractor): The Tractor, All Wheel Drive W/Attachments is a lightweight rubber-tired, diesel-powered tractor equipped with a front end loader and backhoe excavator. It is capable of rapidly excavating a variety of holes, pits, trenches, and earthworks. It is equipped with on-board hydraulic tools, i.e., chainsaw, pavement breaker, and impact wrench.

(b) 250 CFM AIR COMPRESSOR: The 250 cfm Air Compressor is a trailer-mounted unit which furnishes compressed air at a rate of 250 cubic feet per minute, at a pressure of 100 pounds per square inch. It is designed to operate to its rated capacity under widely adverse conditions of heat, cold, rain, and dust and will operate pneumatic tools as well as provide compressed air for bridging and bulk fuel operations. The 250 CFM Air Compressor is an efficient and versatile tool used during all stages of military construction. It is used extensively for drilling, sawing, spray painting, and operating a wide variety of pneumatic tools.

1 Description.

a The 250 CFM Air Compressor consists of a Spiro-Flo air compressor and diesel engine mounted on a four wheel trailer.

b The trailer supports four tool boxes mounted to the frame; two on each side.

c A spare tire is mounted to the draw bar frame.

d A front jack and two rear jacks are mounted to the frame for leveling the trailer when the compressor is being operated.

e The trailer has a mechanical park brake, which also aids in stabilizing the trailer during compressor operation.

f The trailer brakes are an air-over-hydraulic system actuated by the towing vehicle.

2 SAFETY:

a Do not connect the air discharge on this unit into a common header with any other unit of any description, or any other source of compressed air, without first making sure a check valve is used between the header and the unit.

b When connecting sections of hose or connecting a hose to a tool always use safety wire on the coupling half quick disconnect.

c Check all connections. Compressed air is dangerous.

d Always clear the work area of any hazards when using pneumatic tools.

e Ensure the park brake is on before operating the air compressor.

f Always wear proper eye and hearing protection.

g Avoid wearing loose fitting clothes and jewelry.

h Be alert at all times while using pneumatic tools.

i Make sure the air source is off prior to working on a tool.

j Always disconnect the tool from the air power supply when it is not being used.

k Follow the safety rules discussed during the power tools class for similar tools (i.e. circular saw).

3 Tools:

a Oiler, Airline: Used for oiling the pneumatic tools during use.

b Hose Assembly, Rubber. Pneumatic, braided; 250 psi test pressure: comes in 1/2 x 10 ft, 3/8 x 24 inch, 3/4 x 15 ft., 3/4 x 50 ft.

c Hammer, Pneumatic, Portable: Nail driving retaining device, straight rod tool shank; open end handle; universal coupling inlet installed. Used primarily for driving large nails, spikes, and drift pins in heavy timber construction. Can also be used to remove scales and rust from metal.

d Saw, Circular, Portable, Pneumatic: Used for cutting and ripping heavy timber. 12 inch blade 3-7/8 in cut; angle driven; 2500 rpm; with 12 inch combination rip and crosscut blade.

e Blade, Circular Saw: Used with pneumatic circular saw, 12 inch combination rip/cross-cut blade

f Bore, Wood, Pneumatic: Used in heavy timber construction, to bore pilot holes for drift pins and bolts.

g Bit set, Auger: Has a Variety of Diameter and lengths Bits. Used with the wood bore.

h Drill, Pneumatic, Sinker Dry Type: Used in quarry and rock excavations to drill into rock. Weighs 55 pounds, 4-1/4 x 1 inch hex chuck.

i Drill Rod, Rock Drill: Used with the Pneumatic drill. The 250 CFM compressor comes with a variety of drill rods.

j Bit, Star, Rock Drill: Used for rock excavation. Has 4 cutting edges; a center and side clean holes, and tungsten carbide inserts.

k Breaker, Pavement (pneumatic): Used for heavy duty demolition work on concrete, brick, asphalt, and similar materials. 25 pound class and 80 pound class.

l Moil Point, Paving Breaker, Steel: Used to break concrete and rock.

m Chisel, Paving Breaker, Steel: Used to cut asphalt and to break concrete and rock.

n Pick, Paving Breaker: Used for breaking up light asphalt and soil. (NOT CONCRETE)

o Spade, Paving Breaker:

p Rod, Tamping Tool, Paving Breaker: Used to tamp earth.

q Pad, Tamping Tool, Paving Breaker: Used to compact soil in a small area.

r Pump Unit, Centrifugal: Used for pumping water from a foundation excavation, 210 gallons per minute at 25 feet.

s Hose Assembly, Polyester Fiber, Synthetic Rubber Lined: Used as extension hose with the centrifugal pump unit. 2-1/2 inch, 25 ft. long; 400 psi hydrostatic test pressure.

4 Assembly of Pneumatic Tools:

a The first step in assembling a tool is to hook up the coupling half, quick disconnect by connecting it to the universal type hose.

b Between the hose mounted on the compressor and the hose going to the pneumatic tool, you must place the inline (airline) oilier. Insure the oiler;

(1) Is at least half full of oil.

(2) Is placed in the line with the arrow pointing towards the tool to be operated.

(3) Has no longer than ten feet of universal hose between it and the tool.

c Once the hoses are connected, to include the inline air oilier, you are ready to operate the pneumatic tool. Follow these same simple procedures in operating all pneumatic tools.

(c) Hand tools: The Tool Kit, Pioneer, Engineer Platoon consists of hand tools and materials used for clearing land, building emplacements and fortifications, and other manual labor. It is stowed and transported in four chests.

1 Wrecking Bar (1 EA)
2 Crowbar (1 EA)
3 Hammer Sledge, Blacksmith's (6 EA)
4 Tape Measure, 50 & 100 Foot (1 EA)
5 Shovel (16 long, 8 D - Handle)

6 Post hole Digger (2 EA)
7 Earth Auger (1 EA)
8 Marking Crayon (1 DZ.)

b. ASSEMBLY OF BUNKER WALL:

(1) Sill

(a) The sill is the first component part of a bunker to be laid out. It is direct contact with the ground

(b) Sill size is dependent on the type of bunker you are building, normally they are 3" x 12" material. Whatever size material is used at a minimum it must be the same width as the post.

(2) Post

(a) The minimum size lumber required is 6" x 6".

(b) Connect the bottom of the posts to the sill forming a butt joint. The post is secured to the sill using Drift pins.

(1) Drift pins. Drift pins are long, heavy, metal rods used to hold heavy pieces of timber together.

(a) Types. Drift pin may vary in diameter from 1/2 to 1 inch, and in length from 18 to 26 inches.

(b) To place a drift pin, use the wood bore of the 250 CFM for large timber or the brace bit ratchet from the pioneer kit to drill a hole slightly smaller than the diameter of the pin. Drive the pin into the hole, using a 3 lb. Hammer. The pin is held in place by the compression action of the wood.

(3) Cap

(a) The minimum size lumber required is 6" x 6". Caps should be the same width as the posts.

(1) Attach the caps to the top of the posts by the same means as the posts are attached to the sills, scabs may also be used to strengthen the butt joint. Scabs are secured using Nails.

(4) Diagonal Bracing

(a) 3" x 12" material is preferred, but lumber 3" x 6" or larger is acceptable for use.

(b) Run the braces from the top of the post to the sill at an angle. Bracing is secured using 60 D Nails or Bolts. To use bolts, drill a hole the same diameter as the bolt. Two washers and one nut hold the bolt in place.

(5) Sheathing

(a) Normally use 3" x 12" lumber, but any three-inch material is acceptable for use.

(b) Place the sheathing parallel to the ground, attach the sheathing starting at the bottom, working your way to the top of the cap. The sheathing goes on all sides of the bunker, except openings for door and firing ports.

(c) Put the sheathing on the exterior of the shelter. Sheathing is secured using 60 D Nails or Bolts.

c. ASSEMBLY OF BUNKER ROOFS. There are two types

(1) Stringer Roof. Stringers are placed on edge(if stringer is 2X4 the 2″ side would be placed against the Cap with a spacing on center as determined by the designer. A layer of sheathing, 1 or 2 inch, is nailed over stringers. The stringer roof has 7 layers and they are:

(a) Dust Proof Layer: Keeps dirt and dust from falling on Marines that are inside the bunker. Materials needed for this layer are plastic, and empty sandbags. It must extend 1.5 meters on both sides of the bunker.

(b) Lower Cushion Layer: Absorbs the shock that the distribution layer did not move out and away from our bunker. This is the only layer that does not extend beyond the edges of the bunker. The material used in this layer is dirt.

(c) Distribution Layer: Distributes the shock of the explosion out and away from our bunker. Materials used in this layer are made from timber or logs. This layer also extends 1.5 meters on both sides of the bunker.

(d) Water Proof Layer: Keeps the Marines inside dry in the event of heavy rains. This layer contains materials made of plastics. Must extend 1.5 meters on both sides of bunker.

(e) Top Cushion Layer: Absorbs the shock of the initial impact of the round. The materials used in this layer consist of dirt, rocks, and sand bags. It must extend 1.5 meters on both sides.

(f) Burster Layer: Causes enemy ordnance to explode on impact, instead of penetrating then exploding. It is usually one foot thick, but the thicker it is constructed the better the protection is. It is made of rocks, and sandbags. It will also extend 1.5 meters on both sides of the bunker.

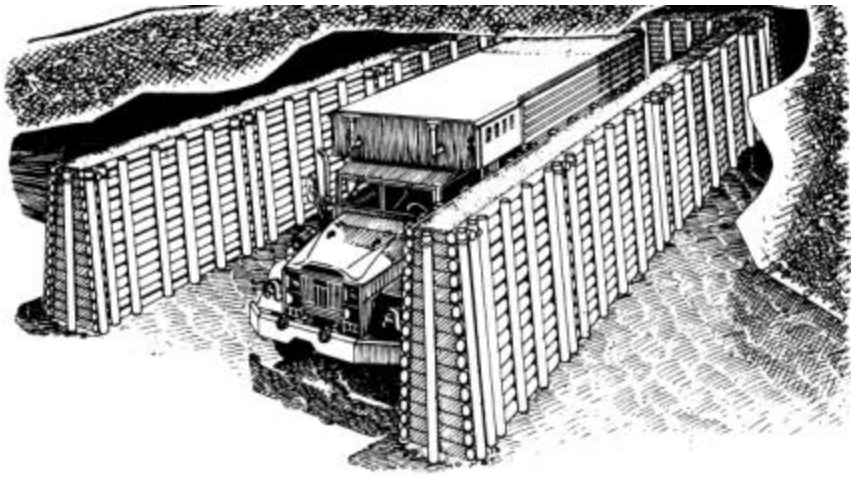
(g) Camouflage Layer: Makes the bunker look natural as possible. Approximately two inches is adequate. Made of materials relative to the area of occupation, (i.e. brush, and dirt).

NOTE: ALL LAYERS MUST EXTEND 1.5 METERS OR 5 FEET ON EACH SIDE OF THE BUNKER ONCE THE DISTRIBUTION LAYER HAS BEEN PLACED.

(2) Laminated Roof: The first layer of lamination will be laid across the shortest distance. (example: 8ft x 10ft bunker the first layer will be laid across the 8 ft distance) and is secured to the caps using 60d and the 3 lb sledgehammer. The Laminated roof is the strongest of the two roof types and does not require two cushion layers or a distribution layer. The required layers are: Dustproof, Cushion, Waterproof, Burster, and Camouflage.

4. REVETMENTS:

a. A revetment is reinforcement to an embankment or a barricade. As an Engineer you will mainly use revetments to support excavated surfaces (underground revetment) from the effects of weather and damage caused by occupation. Revetments can also be used above ground to act as a container to hold earth or rocks to make a wall as shown below.



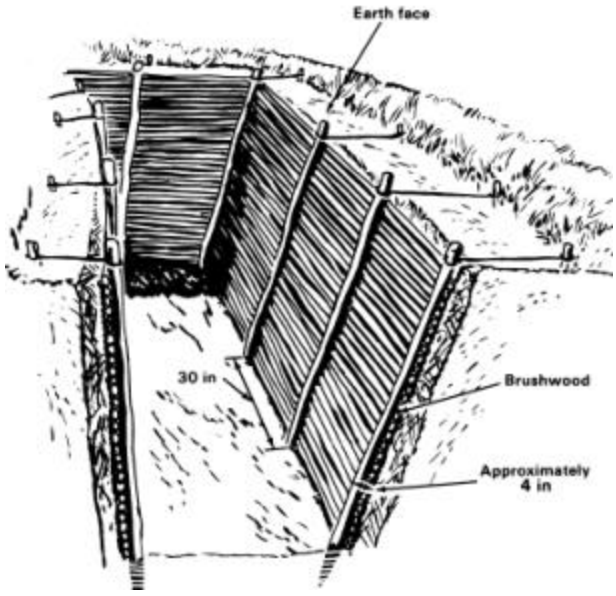
(1) UNDERGROUND REVETMENTS

(a) Brushwood Hurdle. A brushwood hurdle is a woven revetment unit usually 6 1/2 feet long and as high as the revetment wall. Pieces of brushwood about 1 inch in diameter are weaved on a framework of sharpened pickets driven into the ground at 20-inch intervals. When completed, the 6 1/2 feet lengths are carried to the position where the pickets are driven in place. The tops of the pickets are tied back to stakes or holdfasts and the ends of the hurdles are wired together.

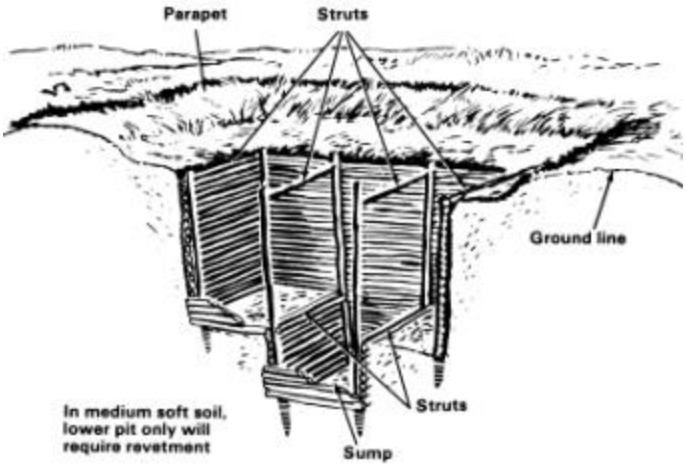
Brushwood hurdle

(b) Continuous Brush. A continuous brush revetment is constructed in place. Sticks are cut on a 45-degree angle and 3 inches in diameter. They are driven into the bottom of the trench in intervals of 30 inches and 4 inches from the revetted earth face. The space behind the picket is packed with small, straight brushwood laid horizontally. The tops of the pickets are anchored to stakes or holdfasts.

Continuous brush revetment

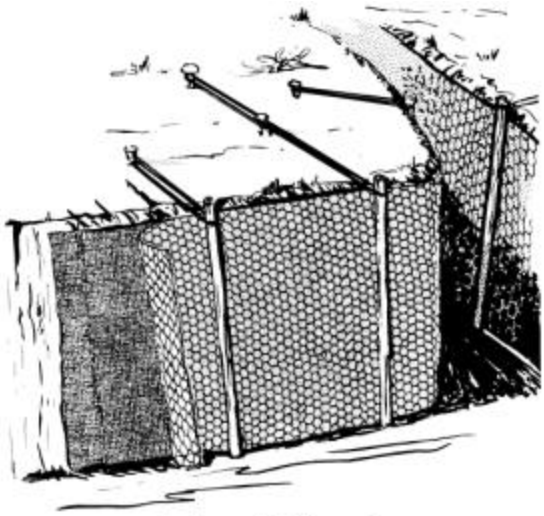


(c) Pole Revetment. A Pole revetment is similar to the continuous brush revetment except, small poles are placed horizontally and cut to length. For faster construction, boards, or planks are used if available. Pickets are held in place by holdfast, or struts.



(d) Corrugated Metal Sheets or Plywood. A revetment of corrugated metal sheets or plywood is durable, rapidly deployed, and is easy to adapt to the size job. It can be overlapped to obtain any height or length.

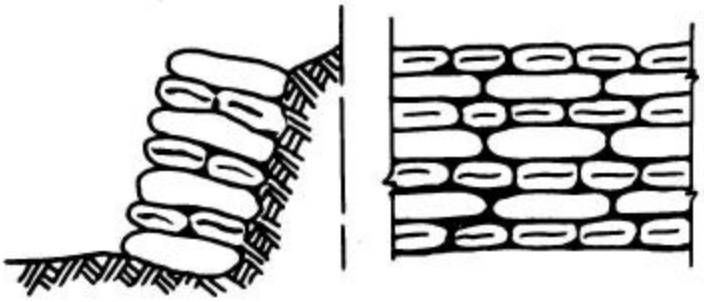
Corrugated metal sheets



Burlap and chicken wire

(e) Sandbag Revetment. The bags are filled about three-fourths full with earth and the choke cords are tied. The bottom corners of the bags are tucked in after filling. The bottom row of the revetment is constructed by placing all bags as headers. The wall is built using alternate rows of stretchers and headers with the joints broken between courses. (When sandbags are placed length wise along the side or front of emplacement or bunker they are called stretchers. Headers will go on top of the stretchers in the opposite direction). All bags are placed so that side seams are on stretchers and choked ends on headers are turned toward the face of the embankment.

Stretchers and headers

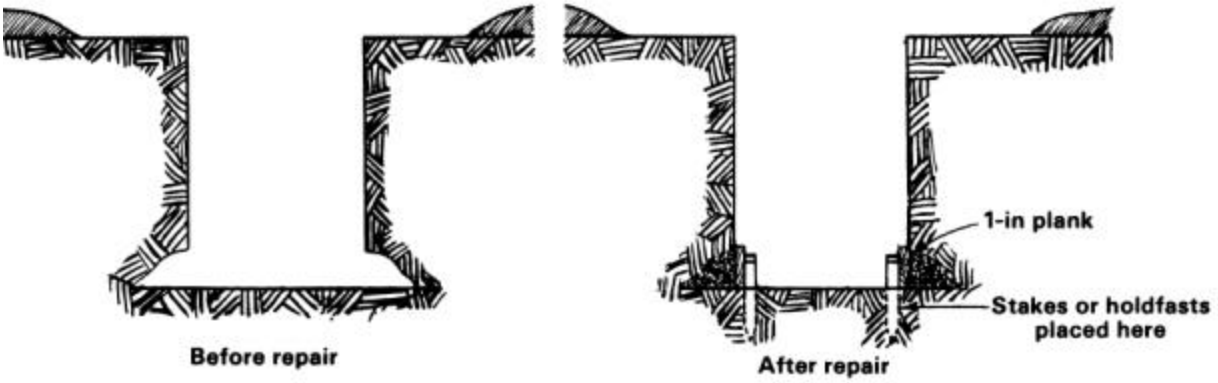


SECTION **ELEVATION**

(f) Concertainer: Is a manufactured revetment material that is designed to replace. A typical concertainer unit is equivalent to 1500 sandbags. Concertainer takes to Marines to set it up and a Bucket loader to fill it. It is used for Bunker construction or Revetments as seen below.

(g) Repairs. If walls crumble at ground level, the soil is removed where it is crumbling, or until firm soil is reached. Sandbags or sod blocks are used to build up the damaged area. If walls are wearing away at the floor level, a plank is placed on its edge and held in with stakes. This method is for use in trench repair.

DAMAGE AT GROUND LEVEL



DAMAGE NEAR FLOOR LEVEL

REFERENCES:

1. MCRP 3-17A/FM 5-34 Engineer Field data
2. TM 08917A-14 250 CFM Air Compressor
3. FM 5-103 Survivability
4. FM 21-75 Combat Skills of the Soldier
5. Bunker Card